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Gain and Pattern Measurements of Large Aspect Ratio Reflectors

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ABSTRACT

This report summarizes the results of absolute gain and radiation pattern measurements on two large aspect ratio reflectors with various primary feed systems. The width-to-height ratios of the reflectors approximated 7.2 to 1 and the focal lengths were approximately one-quarter of the large dimension. The antennas were polarized with the primary feed E-field parallel to the large dimension of the reflectors.

PROBLEM STATUS

This is an interim report; work continues on other phases of the problem.

AUTHORIZATION

NRL Problem 52R08-37

GAIN AND PATTERN MEASUREMENTS OF LARGE ASPECT RATIO REFLECTORS

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INTRODUCTION

In numerous applications, notably in surface search, radiation patterns are required which have a broad beamwidth in one principal plane and a narrow beamwidth in the other. In this report it will be considered that the broad coverage is required in the elevation plane and a narrow beam is required in azimuth. This coverage requirement is frequently met by reflector systems which have a relatively large width to height ratio. The reflector is commonly a section of a paraboloid, a parabolic cylinder, or a shaped beam reflector. The vertical sections of shaped beam antennas are neither parabolic nor straight lines, but specifically curved to result in a far field pattern in the elevation plane which closely approximates some particular function of elevation angle; e.g., $\csc^2\theta$.

The gain of any reflector system may be expressed as:

$$G_p = K4\pi \frac{A}{\lambda^2} .$$

Here G_p is the power gain, A is the projected area of the reflector (the projection being taken on a plane perpendicular to the axis of maximum radiation) and λ is the wavelength. The constant K is defined as the aperture efficiency factor. In general, low values of K result when beam shaping is utilized.

Applications arise in which a minimization of size and weight is of more importance than detailed control of the shape of the radiation pattern in the vertical plane. In these applications the maximum gain possible, consistent with minimum beamwidths in the two planes, is desired. This report is primarily concerned with measurements of aperture efficiency for two typical reflector configurations, each having an aspect ratio, or width to height ratio, of approximately 7.2 to 1. Measurements were made at a frequency of 9760 megacycles, with additional checks being made of performance over a sufficiently large bandwidth to insure that incidental combination of back radiation from the feed with reradiation from the reflector did not cause unusual variations in gain with frequency. The first antenna configuration considered utilized a section of a 9 inch focal length paraboloid with a nominal diameter of 36 inches; this reflector was cut to provide for "offset" feeding. The second basic antenna configuration was based upon a parabolic cylinder with the parabolic curve in the horizontal plane; this antenna had a nominal focal length of 10 inches. In all cases considered, horizontal polarization was utilized.

OFF-SET FED PARABOLOIDAL ANTENNA

An evaluation of the performance of a section of a focus-in-face paraboloid fed with a slot array was of primary interest. The slot array feed was preferred because of the resulting compactness of the antenna system. A diagram of this antenna system is shown in Fig. 1. The focal length of this reflector was 9 inches. A section of the paraboloid with a projected height of 5 inches, starting 1.22 inches above the axis, was utilized. The aperture width at the reflector center line was 34.5 inches. The basic feed was a five-element resonant slot array;¹ the slots were arranged on the center line of the waveguide and were post-excited.²

Two modifications were made to the basic feed array in order to improve the illumination of the reflector. The most important modification was the addition of a triangular shaped parallel plate region with a plate spacing of 0.4 inches. This parallel plate region provides a linear phase taper at the exit aperture and thus results in a conical beam shape; i.e., a beam whose maximum value occurs at a constant displacement angle from the aperture line, independent of the azimuth angle. By adjusting the angle the aperture makes with the face of the feed array and tilting the entire feed assembly in the vertical principal plane, the direction of maximum primary feed radiation may be made to intercept the reflector mid-line in the vertical principal plane, and at two other points which are symmetrically located with respect to this plane. The two symmetrical points chosen in this instance were at the extreme edges of the reflector. Fig. 1 shows the values used for the various angles. The other modification made on the basic slot array was the fitting of "wings" of metal to the exit aperture of the parallel plate region; these wings were each 3 inches wide and were arranged perpendicular to the sides of the parallel plate region. A photograph of the entire experimental assembly showing a complete feed is shown in Fig. 2. The purpose of these "wings" is to provide a sufficiently broad primary radiation pattern in azimuth and to provide a rapid decrease in energy beyond the edges of the reflector.

Radiation patterns for the complete primary feed are plotted in Fig. 3. In taking the plotted azimuth pattern, the feed was mounted in such a way that the values shown at zero and plus and minus 90 degrees accurately represent the illumination at the center and at the extreme ends of the reflector centerline.

A contour plot of the primary feed radiation pattern with the edges and center line of the reflector superimposed is shown in Fig. 4. Corrections for space taper have not been made in plotting this figure. An additional taper

¹ Antenna Engineering Handbook, ed Jasik, pub. McGraw-Hill, 1961, Chap. 9, pp. 9-14

² An Improved Slotted Waveguide Antenna Using Post Excitation, Howard S. Jones, Jr. and Whilden G. Heinard; Diamond Ord. Fuze Labs. TR-1029; 23 Apr 1962

of approximately 6-db at the extreme ends of the reflector center line, with respect to the reflector center, results from the reflector geometry.

This combination of feed and reflector resulted in a measured aperture efficiency of 53.6 percent. Cutting the "wings" on the feed to 0.65 inches resulted in a lowering of the aperture efficiency to 46.7 percent. A summary of the data obtained including beamwidths and sidelobe levels in the principal planes is included in Table 1. Secondary radiation patterns are shown in Fig. 5.

Two additional measurements were made on the cut paraboloid fed with the slot array with 3-inch "wings". A measurement of far out sidelobes showed that beyond the first several lobes the level was more than 30 db down from the peak of the beam. The level of cross polarization was found to be also more than 25 db below the peak of the main beam.

For comparison purposes, the cut paraboloid was fed with a horn with an aperture of 5 inches in the vertical plane and 0.4 inches in the horizontal plane. This horn was in excess of 12 inches long and hence had a quadratic phase error of less than a quarter wavelength at 9760 Mc. The aperture was cut at a 12-degree angle and 3-inch wide wings fitted to the sides in order to approximate the beam shape achieved with the modified slot array feed. A photograph of the resultant experimental arrangement is shown in Fig. 6. Primary feed patterns for this feed are shown in Fig. 7. Again, the primary pattern arrangement was made so that the data plotted give an accurate representation of the levels at the center of the reflector and at the ends of the reflector center line (at plus and minus 90 degrees in azimuth). An aperture efficiency of 45.6 percent was measured for this reflector and feed combination. A summary of sidelobe levels and beamwidths in the principal planes is included in Table 1.

PARABOLIC CYLINDER ANTENNA

A parabolic cylinder 5.563 inches high with an aperture width of 39.75 inches and a focal length of 10 inches was the other reflector configuration considered. The performance was checked with two different feeds. Both feeds were resonant slot arrays of the staggered shunt slot type and were constructed in standard RG 52U waveguide. One feed was an array of 5 slots while the other was an array of 4 slots. A region through the center of the reflector 1 inch wide and approximately 5 inches high was blocked by both feeds. A photograph showing the 5-slot array mounted in the parabolic cylinder reflector is shown in Fig. 8. The rod and plate which appear at the lower edge of the reflector were included to evaluate the effect of intrusion of mechanical elements of importance to an increased scale utilization of this reflector configuration. These structures were found to have insignificant effect upon the performance of the antenna. The primary radiation pattern of the 5-element slot array is shown in Fig. 9. Measurements of aperture efficiency yielded 41.7 percent using a 5-slot array in

standard RG 52/U waveguide and 48.8 percent when a 4-slot array in reduced height guide was used as a feed. Summary data of pattern characteristics are included in Table 1. Secondary radiation patterns for the parabolic cylinder fed with the 5-element slot array are shown in Fig. 10. For both antenna configurations it was noted that far out side lobes and cross polarization were more than 30 db down from the peak of the main lobe.

An attempt was made to increase the efficiency of the antenna configuration using the 5-element slot array by adding wings to this feed to broaden the azimuth primary pattern. It was determined, however, that the addition of even 0.5 inch wings to the sides of this feed (resulting in a total azimuth width of 2 inches) resulted in an intolerable increase in sidelobes in the secondary pattern azimuth plane. The blocking due to this width of feed resulted in 8 db sidelobes in this plane; the primary beam broadening with this width of "wings" is insignificant.

SUMMARY

A series of measurements was performed with the primary objective of determining what aperture efficiency could be obtained from apertures having relatively large width-to-height ratios. The two reflector configurations used each had a width-to-height ratio of approximately 7.2 to 1. The first reflector considered was an offset fed cut paraboloid of approximately twenty-nine wavelengths maximum dimension. An aperture efficiency of 53.6 percent was measured when this reflector was fed with a modified 5-element resonant slot array. The second reflector considered was a parabolic cylinder with a maximum aperture width of approximately thirty-three wavelengths. An aperture efficiency of 48.8 percent was obtained with this reflector fed with a four-element resonant slot array. Although other pattern characteristics were not of primary concern, a summary of beamwidths and sidelobes, and plots of the radiation patterns in the principal planes, are included.

ACKNOWLEDGMENT

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TABLE 1

ANTENNA CONFIGURATION	EFFICIENCY (%)	GAIN (db)	EL BW	AZ BW	EL SL (db)	AZ SL (db)
34.5"x5"x9"f.1. offset fed paraboloid						
1) Horn feed, cut to give conical pattern, 3" plates on each side	45.6	28.3	12 ⁰ 8	2 ⁰ 0	12.8	17.0
2) 5-element slot array with parallel plate prism to give conical pattern						
a) 3" plates on each side.	53.6	29.0	13 ⁰ 5	2 ⁰ 0	20.5	18.0
b) .65" plates on each side.	46.7	28.4	Not meas.	2 ⁰ 0	Not meas.	16.3
3) 4-element slot array with parallel plate prism .65" plates on each side	46.7	28.4	12 ⁰ 7	2 ⁰ 1	18.7	16.5
39.75"x5.563"x10"f.1. parabolic cylinder fed with 5-element slot array						
1) Fed with 5-element slot array (staggered slots in standard guide)	41.7	29.0	13 ⁰ 8	1 ⁰ 9	28	22.8
2) Fed with 4-element slot array (staggered slots in reduced height guide)	48.8	29.7	14 ⁰ 6	1 ⁰ 8	25.2	19.5

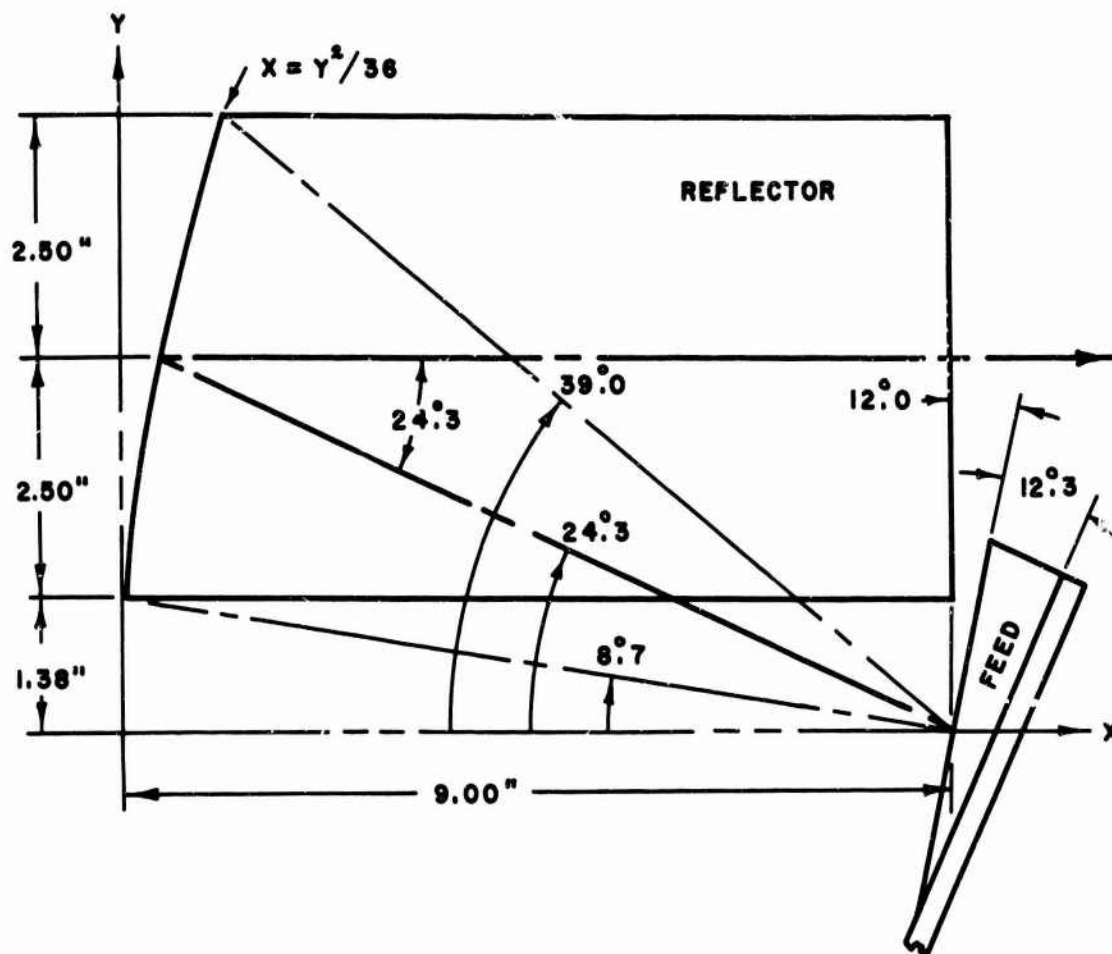


Fig. 1 - Geometry of off-set paraboloidal section

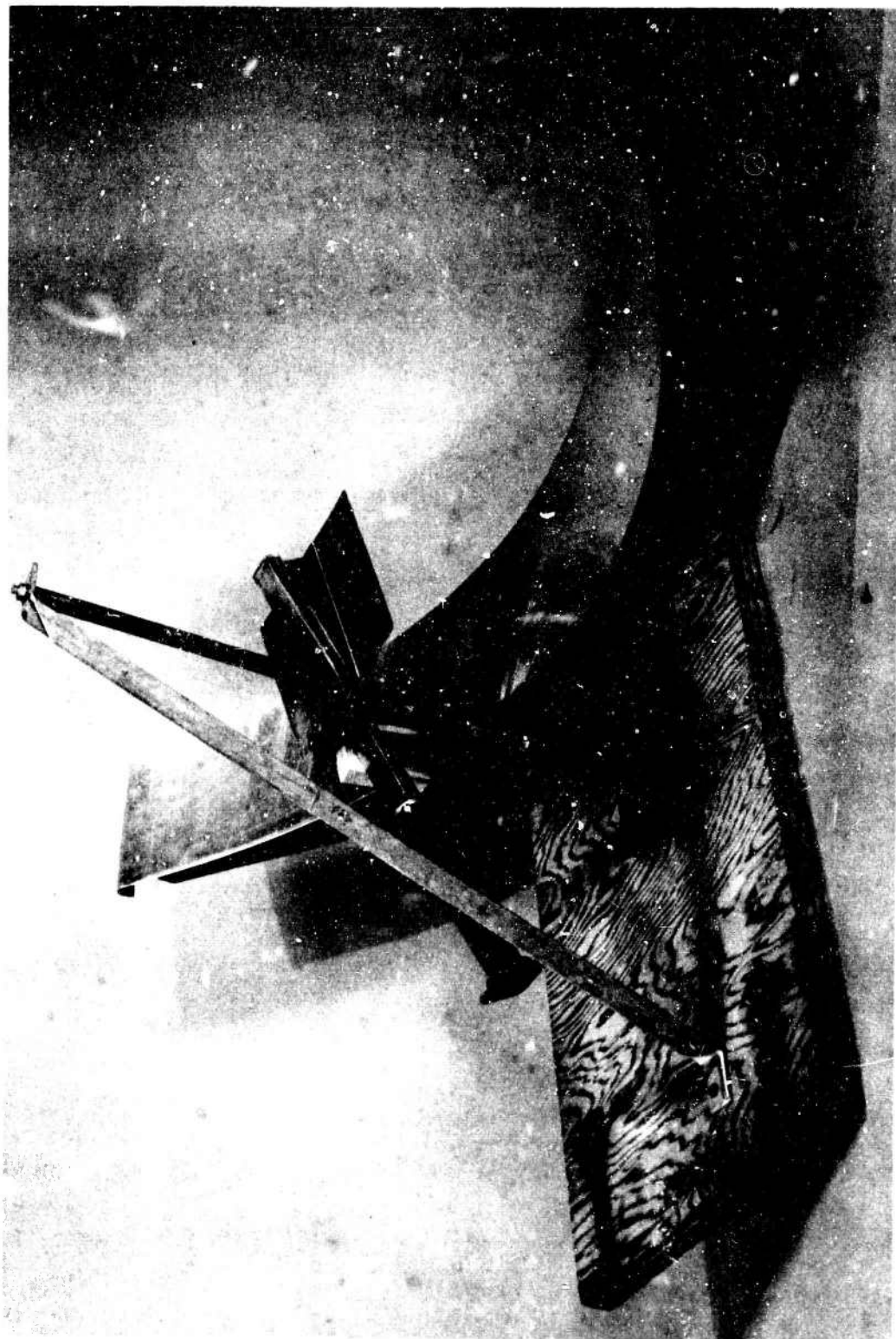


Fig. 2 - Off-set fed paraboloidal section, fed with modified 5-element slot array

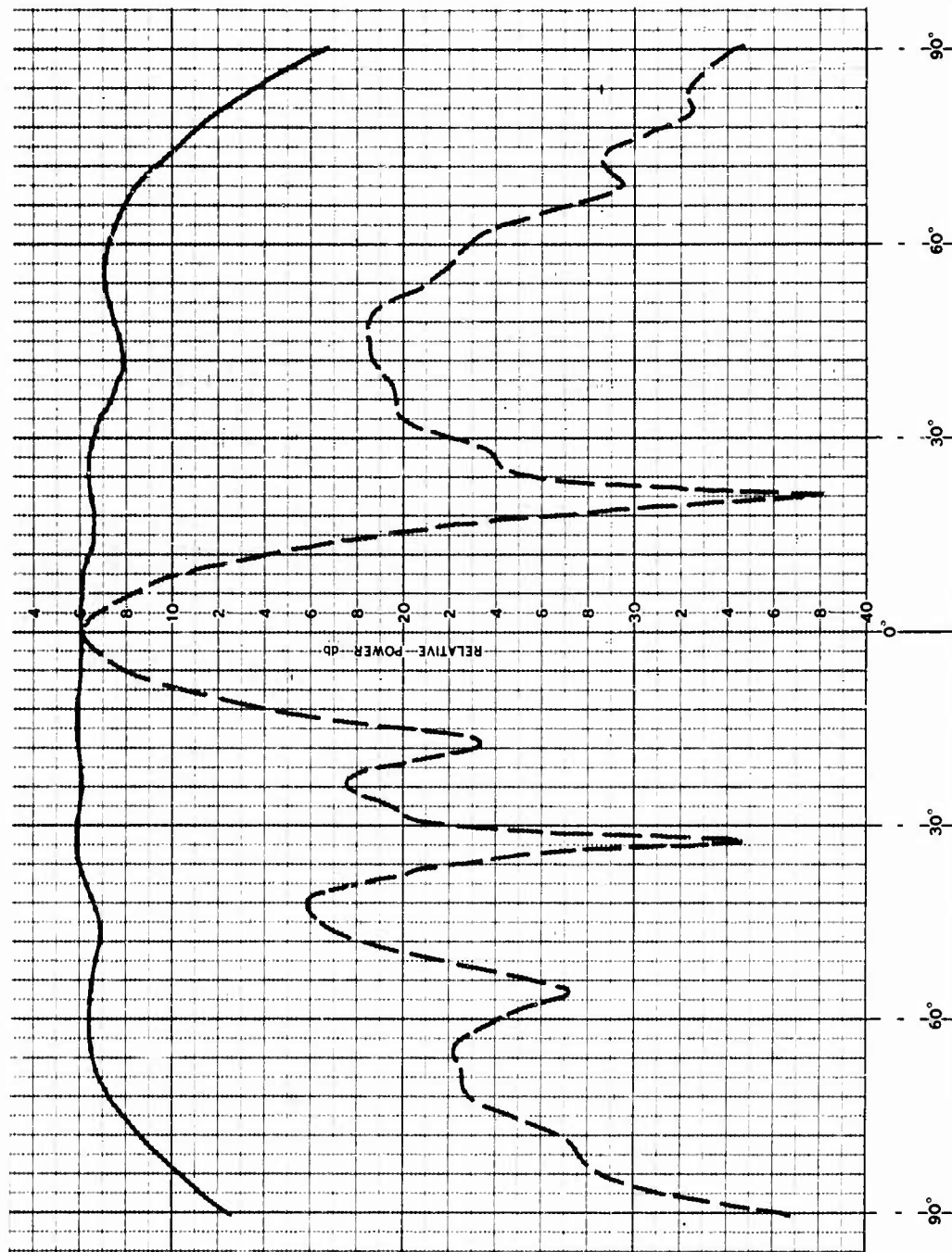


Fig. 3 - Radiation patterns of 5-element slot array
 --- elevation plane — azimuth plane

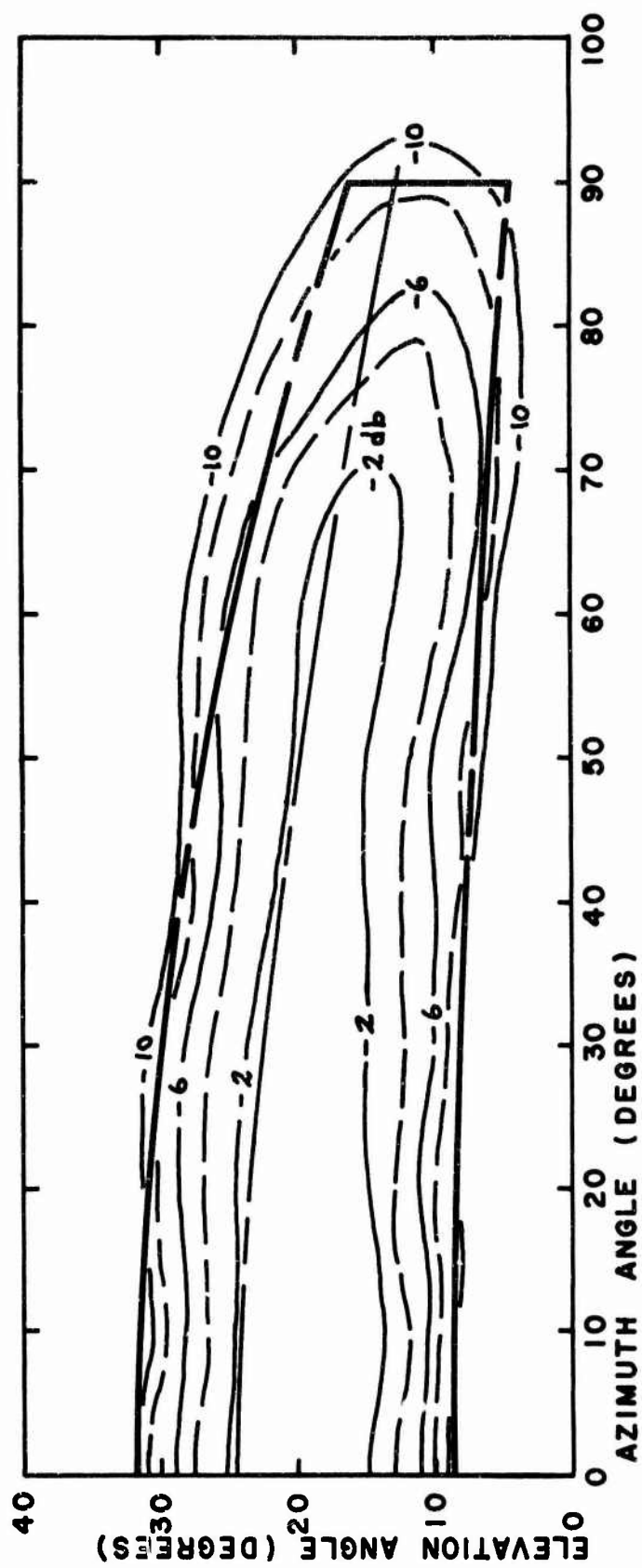


Fig. 4 - Contour plot of primary radiation from the modified 5-element slot array

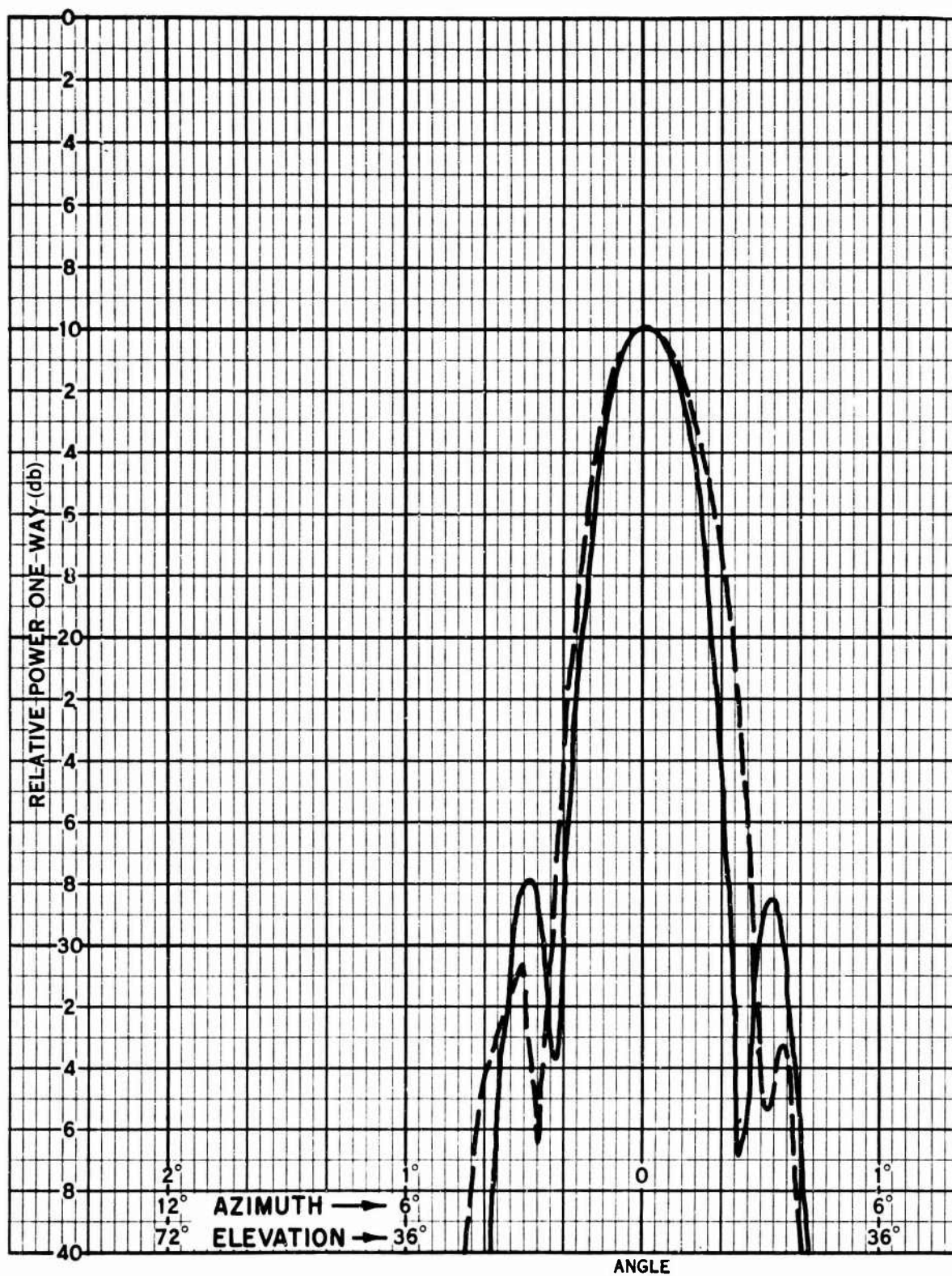


Fig. 5 - Radiation patterns of paraboloidal section fed with the modified 5-element slot array
 --- elevation plane — azimuth plane

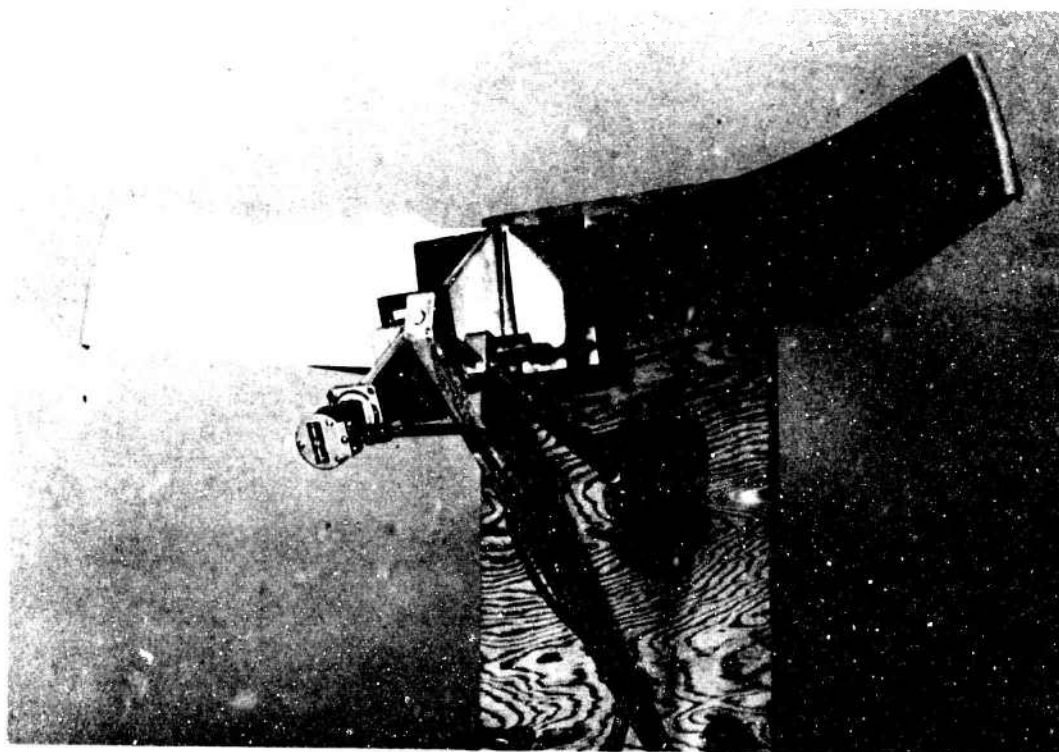


Fig. 6 - Off-set fed paraboloidal section fed with horn

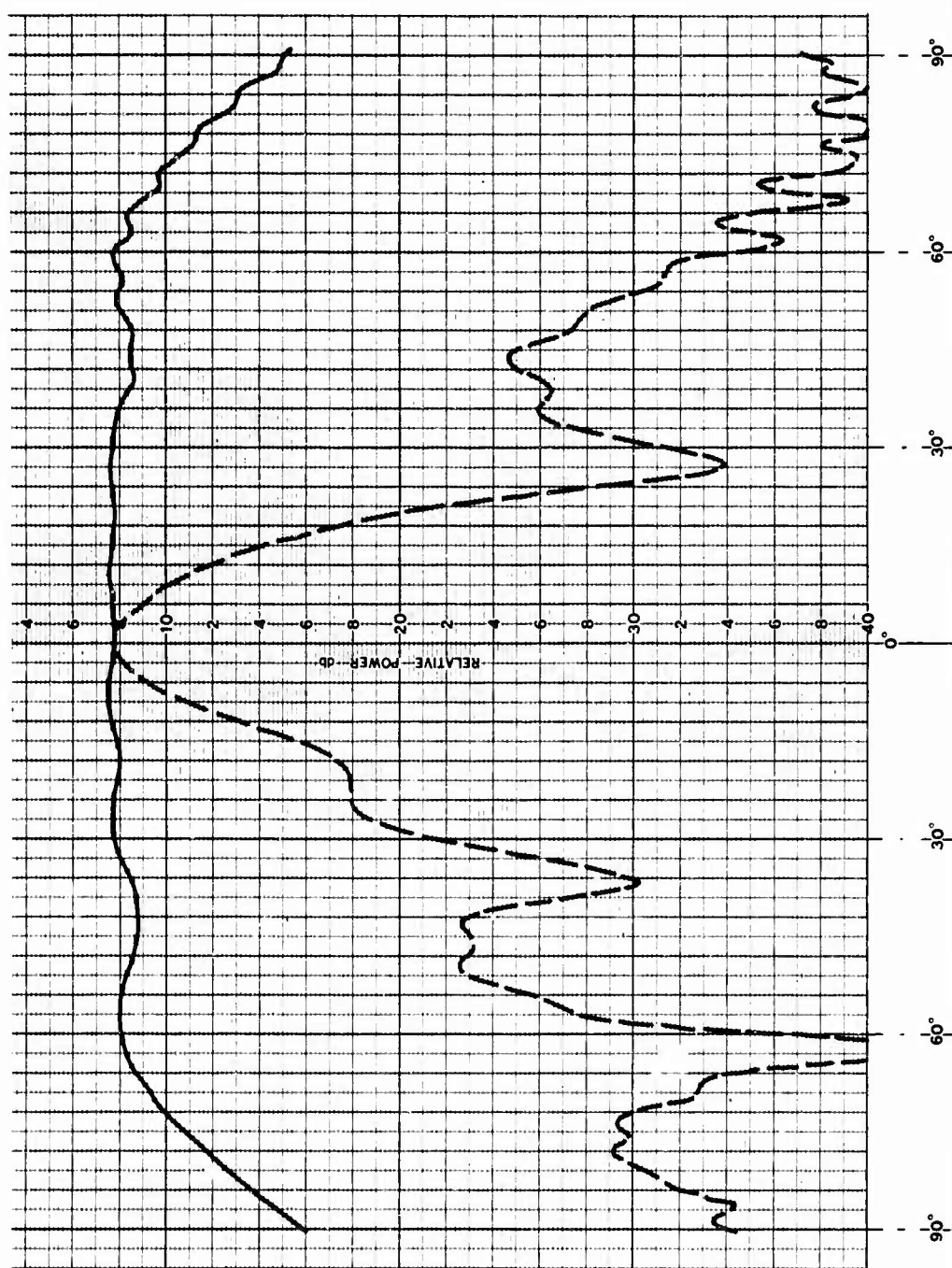


Fig. 7 - Radiation patterns of horn feed
 --- elevation plane — azimuth plane

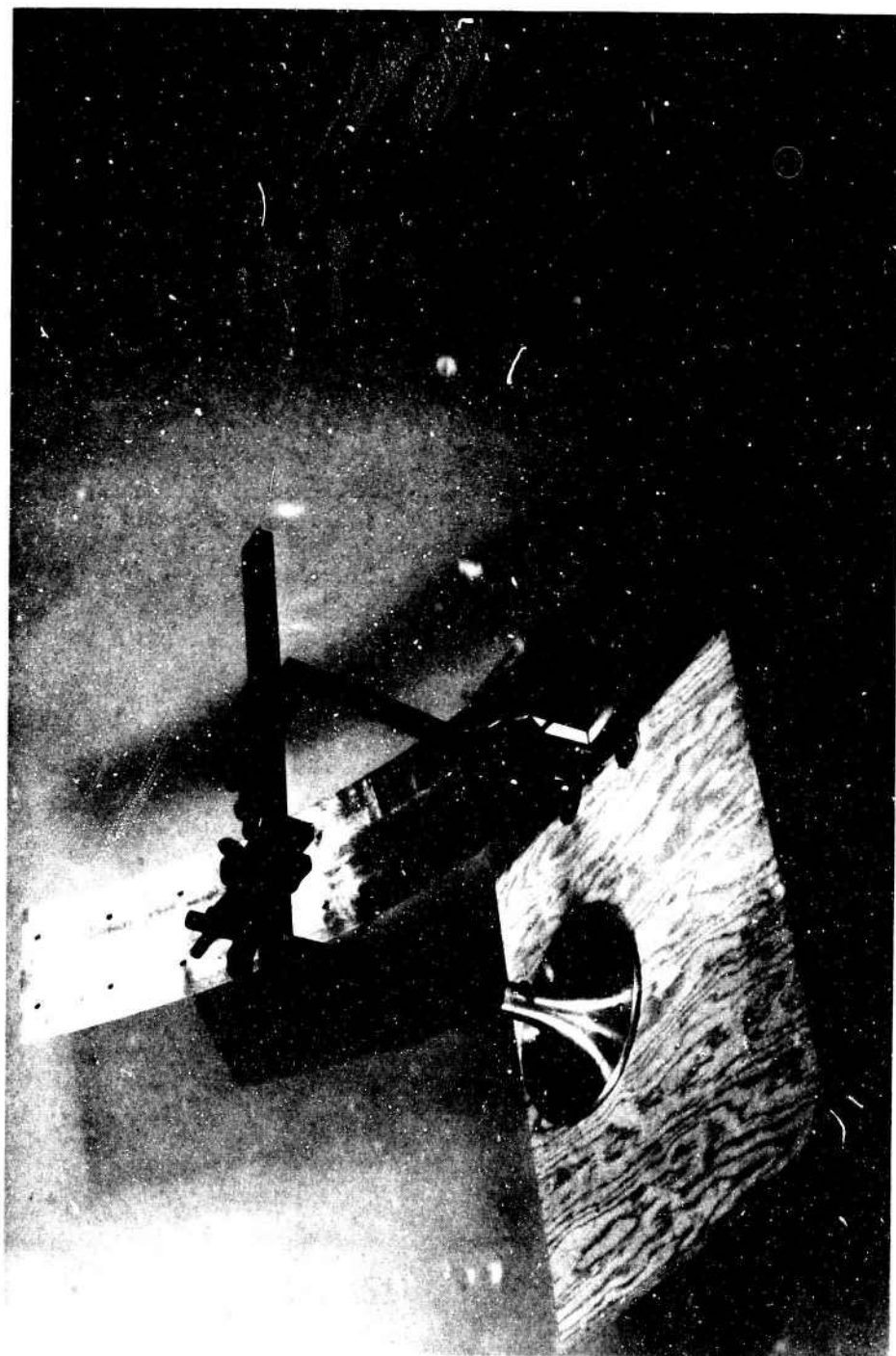


Fig. 8 - Parabolic cylinder fed with 5-element slot array

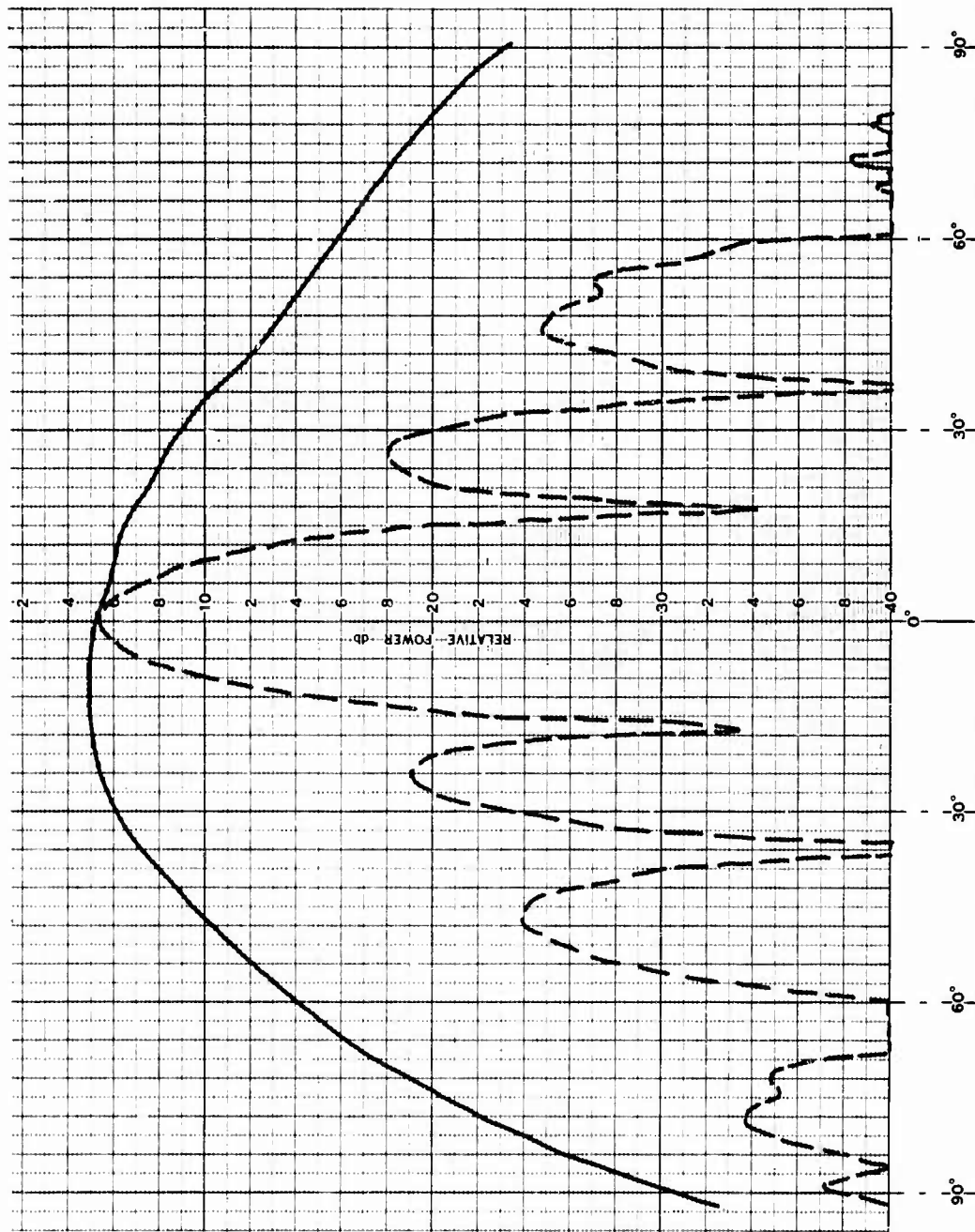


Fig. 9 - Radiation patterns of 5-element slot array
 used to feed parabolic cylinder
 --- elevation plane — azimuth plane

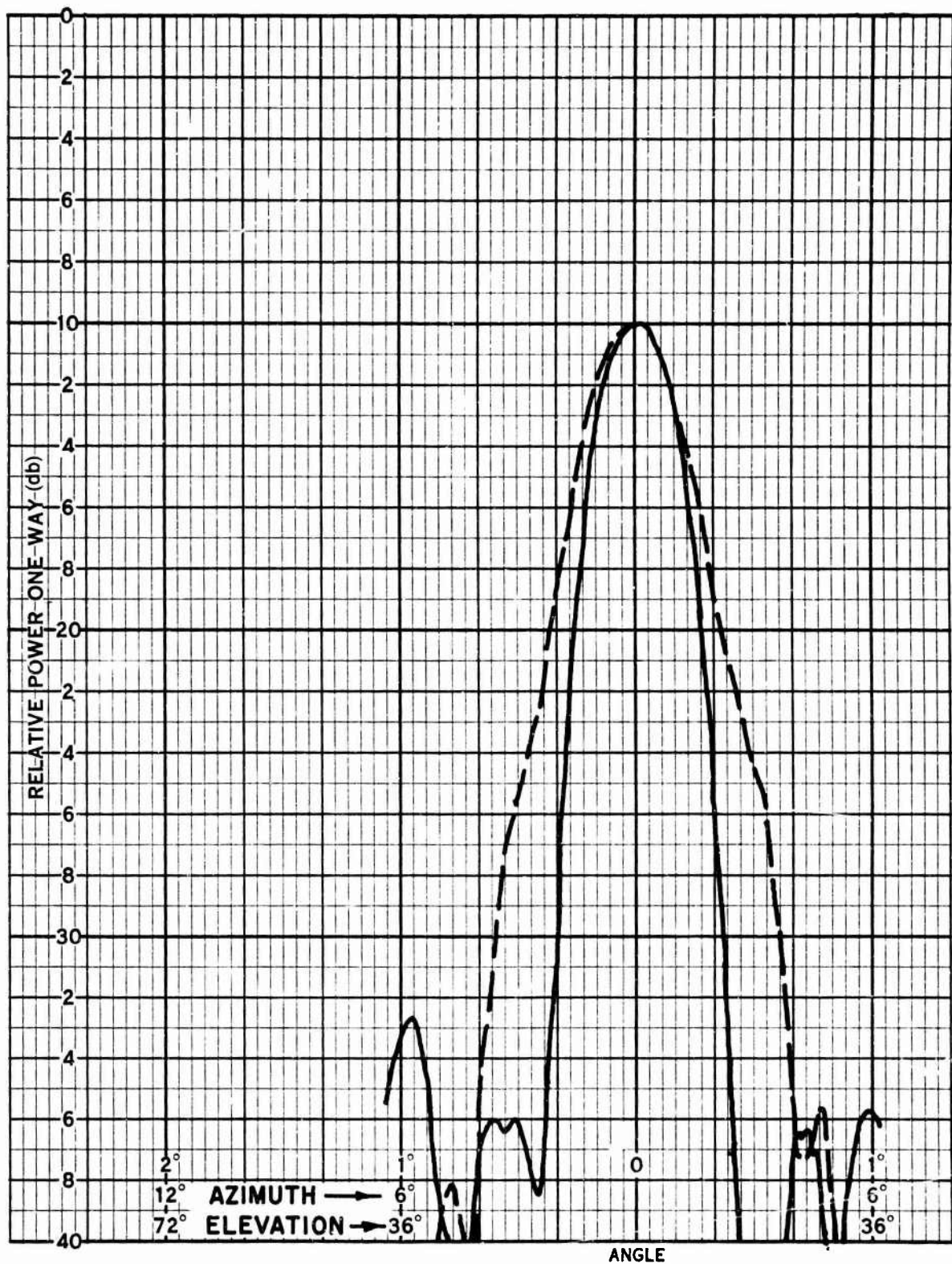


Fig. 10 - Radiation patterns of parabolic cylinder fed with
5-element slot array
--- elevation plane — azimuth plane